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EARTH'S RADIATION BELTS AT 180 — 250 KM HEIGHTS

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EARTH'S RADIATION BELTS AT 180 — 250 KM HEIGHTS

(Radiatsionnyye poyasa Zemli na vysotakh 180 — 250 km)

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ABSTRACT

The scintillating and gas-discharge counters installed aboard the 3rd spaceship allowed the study of the distribution of ionizing radiations in the 180 — 250 km altitude range, the establishment of the position and intensity of radiation belts at these altitudes, and a comparison with the results of similar measurements in the 307 — 339 km altutude range, obtained during the flight of the 2nd spaceship.

author

COVER-TO-COVER TRANSLATION

The radiometric apparatus installed aboard the 2nd Soviet spaceship-satellite provided the possibility of studying the cosmic ray radiation distribution and radiation belts in the 307— 339 km altitude range.

The third Soviet spaceship, launched on 1 December 1960 in the orbit with a 180 km perigee and 250 km apogee with a 65° inclination toward the equator plane, allowed to track the intensity variation and the geogrphic position of the radiation belts at passing to lower altitudes.

The radiometric instrumentation of the latter differed little from that of the former [1], and consisted of a scintillation and a gas-discharge counters. The FEU-15 scintillation counter, provided with a NaJ(Tl) crystal, allowed the determination of the counting rate of particles with a 25 keV energy threshold and the aggregate energy liberation in the crystal by the FEU anode current. The NaJ (Tl) crystal had the shape of a cylinder 14 mm high and 30 mm in diameter. Data of all counters were transmitted once every three minutes and received by a 24-hour memory device.

The general pattern of pickup readings from the 3rd spaceship is quite similar to that obtained by the 2nd spaceship [2]. At spaceship motion in equatorial regions toward high latitudes the counting rate of the gas-discharge counter increased from 0.8 to 3.2 pulse/cm^2 sec, while the energy liberation in the crystal rose from $7.5 \cdot 10^6$ to $3.7 \cdot 10^7$ eV/cm^2 sec, and the FEU counting rate — from 3 to 12 pulse/cm^2 sec. The satellite's passing through radiation belts areas was accompanied by a sharp increase in the counting rate of the scintillation counter, and in a series of cases of other pickups.

In Fig. 1 (next page), squares indicate the points where the counting rate of the scintillation counter substantially exceeded the cosmic background. For comparison similar points obtained in the course of measurements aboard the 2nd spaceship are marked by circles. Conjugated points were found for certain points of the Northern and Southern hemispheres, which are indicated by crosses. The basic and the conjugated point are joined by a dashed line. One may see from Fig. 1 that the zones of increased radiation, determined by both spaceships, coincide with one another. The unambiguous link of zones of increased radiation in the Northern hemisphere with those of the Southern hemisphere (created by the same lines of force of the geomagnetic field) constitutes the proof that these zones belong to the outer radiation belt. The only exception is the region of the South Atlantic, which is to be examined separately.

For a more detailed analysis we superimposed the indications obtained from the scintillation counters' readings of the 2nd and 3rd spaceships (respectively the upper curve I and the lower curve II of Fig. 2). The time scale in the abscissa axis

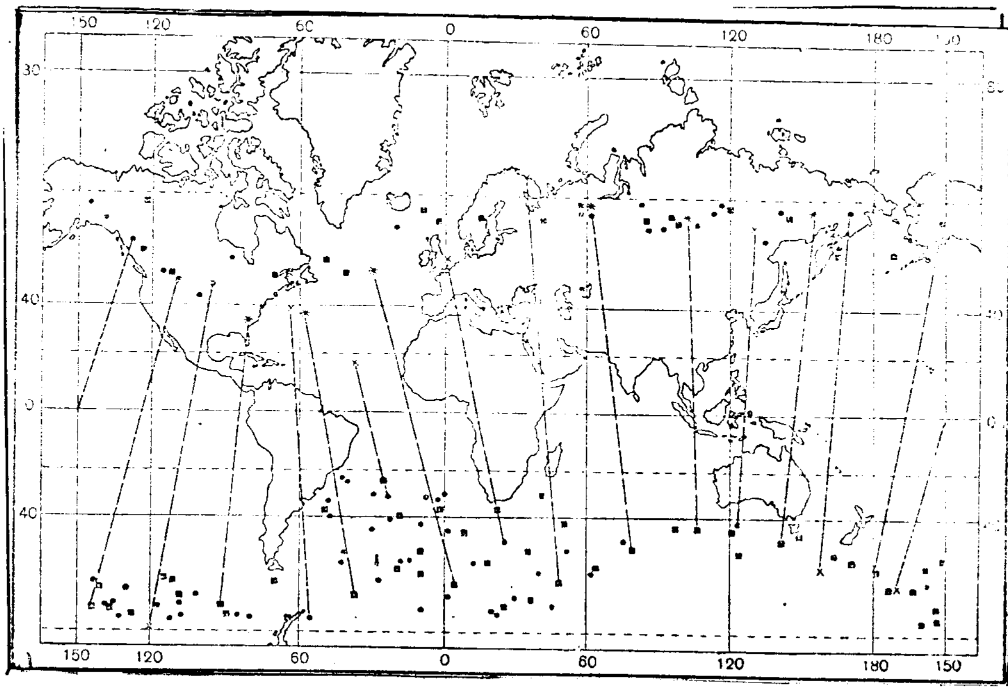
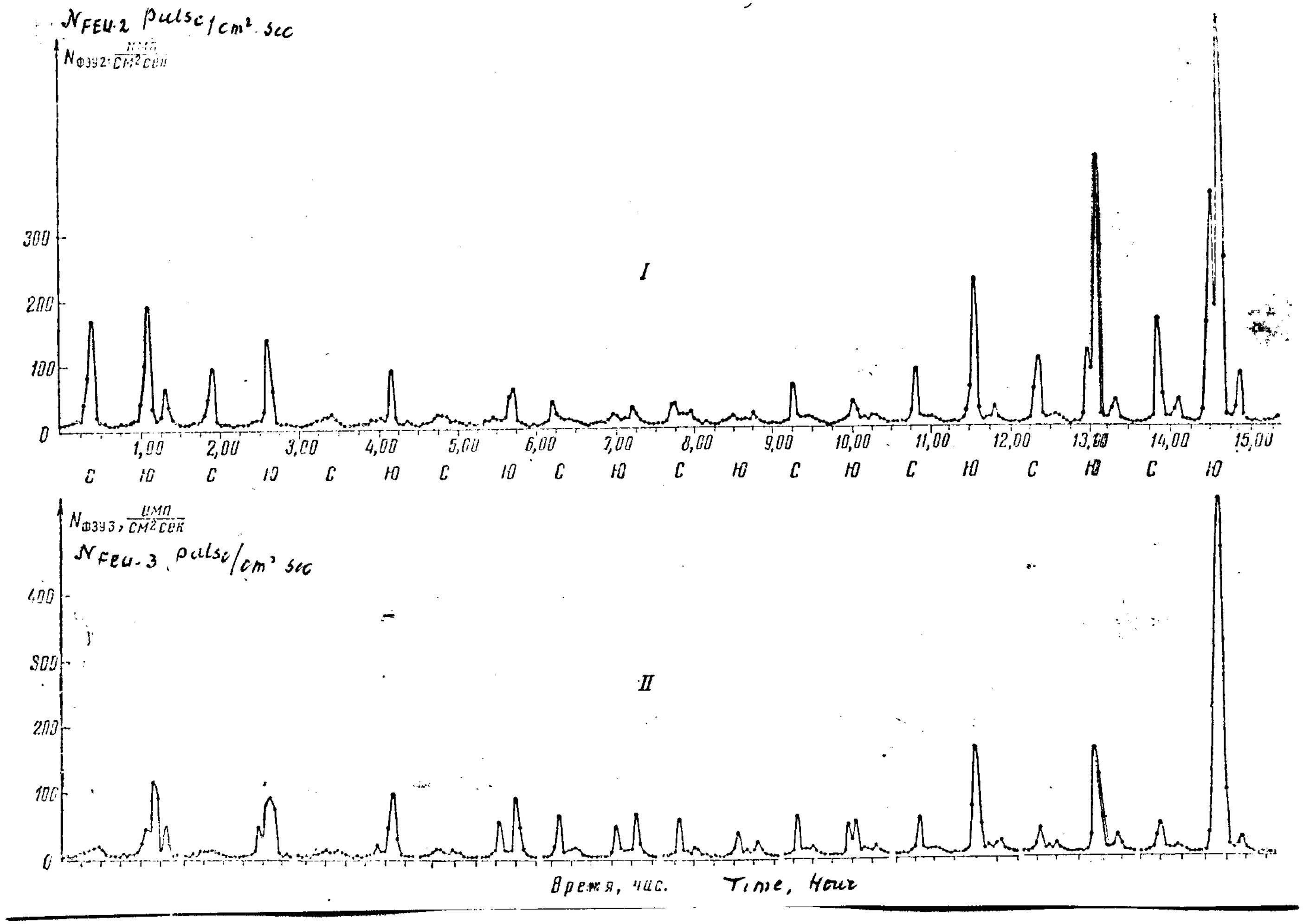


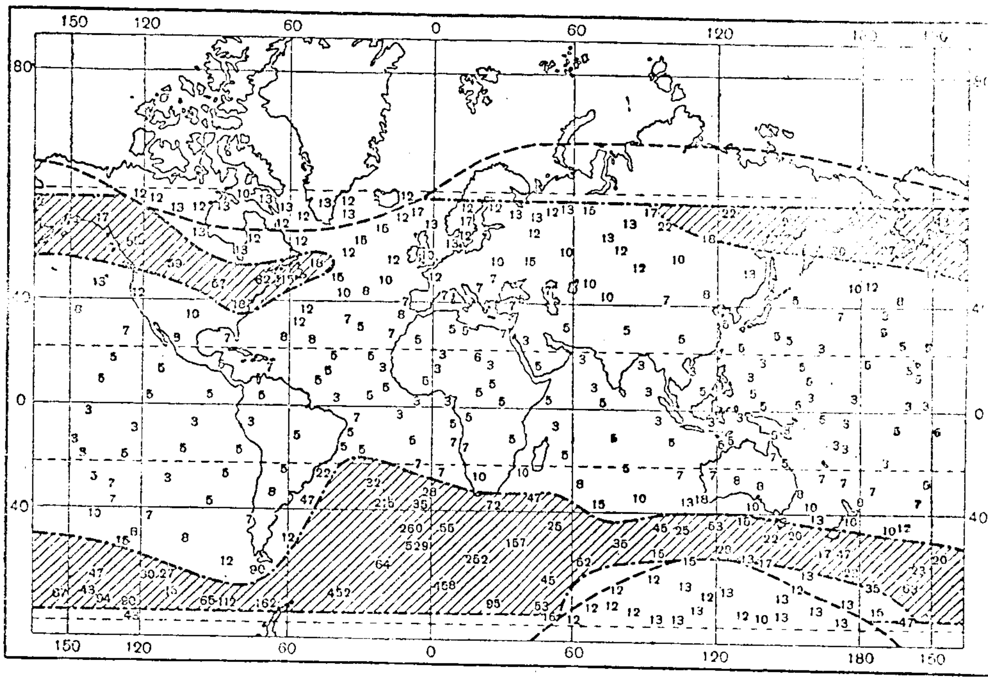
Fig. 1

of the lower curve has been broken up at different places to allow for the "difference in the course" at the expense of the non-similarity of revolution periods of the 2nd and 3rd spaceships. The portions of the graphs, related to the Southern and Northern hemispheres, are respectively marked by (for South) and C (for North). As may be seen from Fig. 2, a rather good agreement exists for the position and the intensity of counting rate maxima of curves I and II. This also suggests that the position of the outer radiation belt underwent no substantial variations during the time between the flights of the 2nd and 3rd spaceships.



NFEU-2 pulse/cm². sec
Nфэу2, имп/см² сек
300
200
100
0
I
1,00
2,00
3,00
4,00
5,00
6,00
7,00
8,00
9,00
10,00
11,00
12,00
13,00
14,00
15,00
С Ю С Ю С Ю С Ю С Ю С Ю С Ю С Ю С Ю С Ю
Nфэу3, имп/см² сек
NFEU-3, pulse/cm² sec
400
300
200
100
0
II
Время, час.
Time, Hour

F I G. 2



Фиг. 3

FIG. 3.

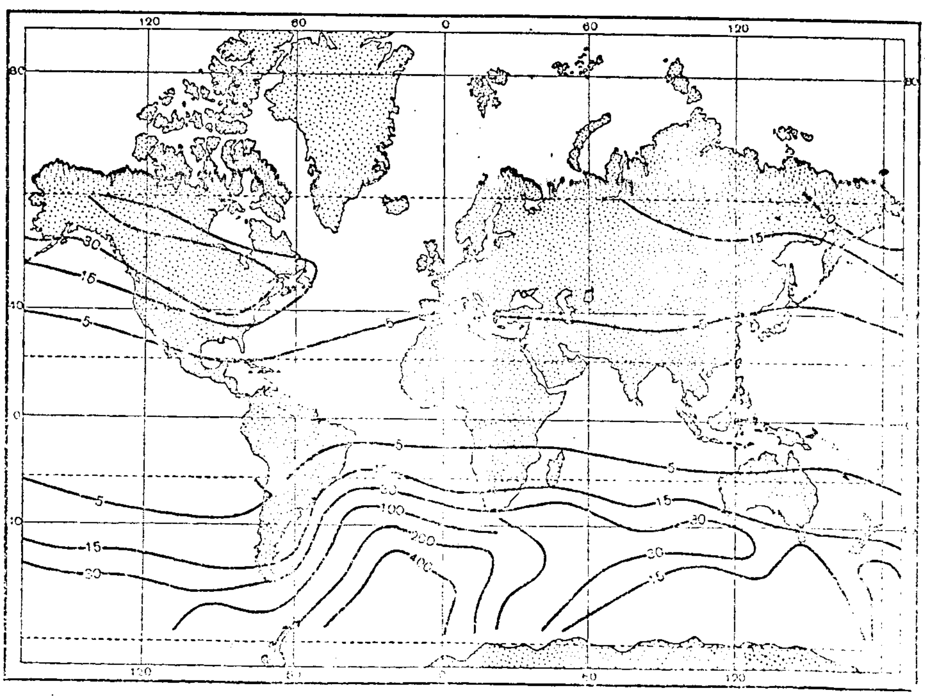


FIG. 4.

The geographical distribution of radiation intensity, registered by the scintillation counter, is indicated in Fig. 3 and 4, where the numbers refer to the counting rate in pulse/cm^2 sec. The regions of increased intensity that cannot be explained by the latitude effect of cosmic rays, are outlined by a dash-dotted line, and shaded. Dash lines designate the isochasms of maximum aurora recurrence. Plotted are in Fig. 4 the lines of equal intensity obtained by way of finding the coordinates of the intersection points of the experimental curve (Fig. 2, lower curve) with the straight lines corresponding to counting rates of 5, 15, 30, 100, 200 and 400 pulse.cm^2 sec.

In comparing with the data obtained in the 2nd spaceship, a small narrowing of the outer radiation belt's band is observed in both hemispheres.

A relative brehmstrahlung intensity decrease in the outer belt for the 3rd spaceship as compared with data of the 2nd spaceship is characterized in Table 1 hereafter :

TABLE 1

Region	I_2 / I_3
North America	1.7
Siberia	8.5
Europe and No.Atlantic	3.5
Indian Ocean	1.4
South Pacific	1.i
Australia	1.0
South Atlantic	0.6

It may be seen from that Table that in the Southern hemisphere the radiation intensity of the outer belt had hardly decreased (in the South Atlantic it even increased), while a 1.7 to 8.5 times intensity decrease is observed in the Northern hemisphere. It must be noted that the flight of the 2nd spaceship took place under conditions of a moderate magnetic storm, while that of the 3rd spaceship started immediately after a rather strong ($K = 8$) magnetic storm [3].

That is why the altitude course of intensity, obtained by way of direct superimposition of data may possibly be distorted. However, taking advantage of the fact that the orbit of the 2nd spaceship-satellite was nearly circular, and that of the 3rd — more eccentric, one may determine the altitude course of radiation intensity at distances of 185 to 235 km from the Earth according to measurements aboard the 3rd spaceship, by assuming that this course is identical in both hemispheres. At the same time, the data obtained in the 2nd spaceship my be used for normalization. Taking for the measure of radiation intensity the height of the peaks of Fig. 2 (upon substracting the cosmic radiation "background"), the following results are obtained:

TABLE 2

Number of the point	Counting rate of the scintillation counter N_{sc} pulse/cm^2 sec.	Energy liberation in the crystal MeV/cm^2 sec	Counting rate of the gas-discharge counter N_r pulse/cm^2 sec
1	112	45.1	2.87
2	90	33.8	1.97
3	11.7	16.9	1.48
4	46.8	28.2	1.89
5	21.7	30.1	1.97
6	5.0	11.3	1.15
7	6.7	11.3	0.98
8	8.4	11.2	0.91
9	5.0	13.1	0.99
10	5.0	9.4	0.83
11	3.3	9.4	0.66
12	5.0	9.4	0.90
13	5.0	15.0	1.15
14	32.0	35.7	2.13
15	215.0	71.5	3.44
16	530.0	127.8	5.00
17	458.0	131.6	5.17
18	95.2	52.6	3.44
19	15.0	39.5	3.12

According to the measurements aboard the 2nd spaceship-satellite, the outer belt's radiation intensity was 2.2 times higher in the Southern hemisphere (mean altitude above ground of about 330 km) than in the Northern hemisphere (mean altitude of about 320 km). A similar ratio computed according to measurements aboard the 3rd spaceship (mean altitude in the Southern hemisphere — 235 km, and in the Northern — 185 km) was 4.4. Hence we may conclude that the radiation intensity decreases in the outer belt 1.9 times at passing from 235 to 185 km altitude.

The region of increased radiation in the South Atlantic underwent more complex variations with the altitude change, contrary to what happened in the above-examined regions of the outer radiation belt. Circles indicate in Fig. 5 the points obtained during the flight of the 3rd spaceship through that region. The pickup readings at these points are compiled in Table 2 (preceding page), while one of the flight convolutions is plotted in Fig. 6. It must be noted that the point numbering is the same for the Fig. 5 and 6 and for Table 2. Plotted also are in Fig. 5 the curves of equal radiation intensity (solid lines), obtained during the measurement of scintillation counter's rate. The number along the lines correspond to counting rates in pulse/cm^2 sec. Dash lines are portions of 3rd spaceship's trajectory, while the dash-dotted lines stand for the lines of equal magnetic field intensity in oe. The black dots indicate the points, where protons were observed in the second spaceship.

The spatial position of the South Atlantic region of increased radiation has changed. If a "slit" could be noted between the outer and inner belts aboard the 2nd spaceship (for example points 11, 12, 13, 14 in Fig. 1 of reference [4]), in which the brehmstrahlung values took th 154, 344, 178 and 608 pulse/cm^2 sec. respectively, the brehmstrahlung intensity reached a maximum in the slit region along an analogus convolution of the 3rd spaceship — respectively 32, 215, 530 and 458 pulse/cm^2 sec. Besides, the whole region of South Atlantic anomaly notably drifted northwestward by comparison with the position determined in the 2nd spaceship-satellite. It is possible that such displacement is the consequence of the magnetic storm of 30 November – 1 December 1960, just as is the fact that at altitude decrease by 100 km the brehmstrahlung intensity in that region not only decreased, but even somewhat increased (Table 1). It is also quite possible that we are confronted here with some new phenomenon, taking place in the inner radiation belts' boundaries.

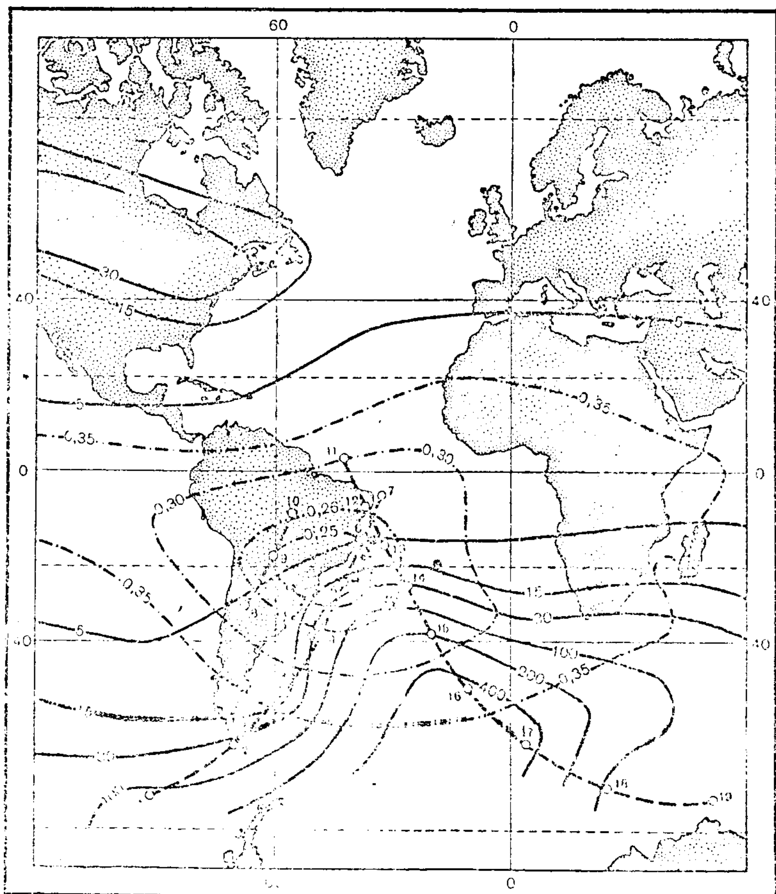


Fig. 5

The estimate of brehmstrahlung γ – quanta energy from the inner belt electrons, averaged by all the points where this belt is observed, gives the quantity $E_\gamma \approx 200$ keV. In a reasonable assumption concerning the mean energy of electrons provoking this brehmstrahlung (for example $E \approx 3 \cdot 10^5$ eV), one may estimate the electron fluxes in the outer radiation belt at the given altitudes. Thus, to the intensity level of 400 pulse/cm^2 sec corresponds an electron flux of $2 \cdot 10^5$ particle/cm^2 sec.

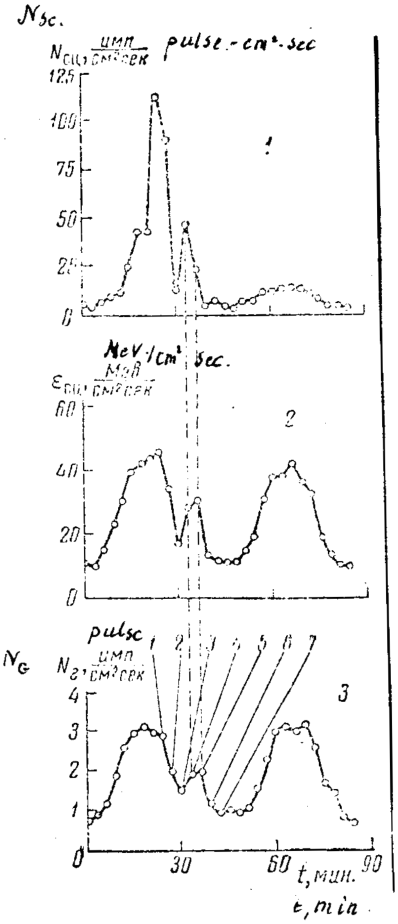


Fig. 6.

A subsequent comparison with the results obtained at measurements aboard the 2nd spaceship attests, that the intensity of the proton component decreased significantly. If earlier the proton emission was observed in at least eight points of the flight trajectory (these points are marked by black circles in Fig. 5), at this time it makes a notable contribution only in the points 4 and 5 (see Fig. 5 and 6).

Indeed, after substracting the cosmic background, the intensity of the charged radiation registered by the gas-discharge counter, is respectively of 0.72 and 0.92 pulse/cm^{2}sec, and the maximum contribution from brehmstrahlung registering in this detector cannot exceed 0.35 pulse/cm^2 sec for the point 4 and 0.15 pulse/cm^2 sec for the point 5, for the effectiveness of brehmstrahlung registration by the gas-discharge counter does not exceed one percent, while the brehmstrahlung intensity in the points 4 and 5 constitutes according the scintillation counter data 35 and 15 pulse/cm^2 sec respectively (after substracting the cosmic background).

efficiency is equal for all the observation cases of the outer belt to 0.3 ± 0.1 percent as an average, and the brehmstrahlung contribution to gas-discharge counter readings is less than that considered above. Thus the intensity of the gas-discharge counter counting rate at points 4 and 5 cannot be explained by brehmstrahlung registration. Besides, at passing from the point 4 to 5 the counting rate of the scintillation counter drops more than twice, while the energy liberation in the crystal and the gas-discharge counter's rate increase (see curves 2, 3 of Fig. 6). This points to the fact that by comparison with point 4 the share of charged particles increases significantly in the composition of the resistered radiation in point 5, as that of brehmstrahlung decreases.

This is interesting to note because point 5 is situated in the center of the Brazilian magnetic anomaly, i. e. in the region where most of the inner belt protons' observations were effected aboard spaceship 2, while point 4 is at the edge of that region, just as are all the other points having been subject to measurements. Inasmuch as the existence of high-energy electrons ($E_e > 5$ MeV) is difficult to assume, since they might then penetrate directly inside the spaceship and induce the corresponding readings, it is more likely that the radiation registered at points 4 and 5 is due to protons from the inner radiation belt.

According to measurements aboard the 2nd spaceship, the counting rate of the gas-discharge counter corresponded near these points ~~to an inten-~~ sity near 10 particle/cm^2 sec. Measurements aboard the 3rd spaceship show that it decreased to 2 particle/cm^{2}sec, thus, accounting for the cosmic ray background at that geomagnetic latitude, the intensity of proton radiation diminished by almost one order at passing from 320 km to 220 km altitude.

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